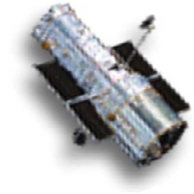
Hubble Facts



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Hubble Space Telescope

SERVICING MISSION IMPROVEMENTS TO TELESCOPE

The Hubble Space Telescope's purpose is to probe the farthest and faintest reaches of the cosmos. Crucial to fulfilling this objective is a series of on-orbit servicing missions to continually correct and improve the Hubble vehicle. Since Hubble was originally placed into orbit on April 25, 1990 it has been serviced four times, with a fifth servicing mission scheduled for mid 2005.

Servicing Mission 1
The First Servicing Mission (SM1) in December 1993 corrected the primary mirror optics with the Corrective Optics Space Telescope Axial Replacement (COSTAR) and provided an opportunity to conduct the first planned maintenance on the observatory. Astronauts also installed Wide Field/Planetary Camera 2 (WFPC2), a next-generation instrument that had built-in optical correction. A number of components were replaced due to failures: Magnetometer Sensing Systems, Solar Array Drive Electronics, Rate Sensing Units (gyroscopes), and Fuse Plugs. These were replaced with identical units, while others were replaced with upgraded versions. The replacement of the gyroscopes restored critical redundancy for science.

One of the most significant infrastructure improvements resulted from the replacement of the degraded original Solar Arrays. The new arrays increased available power by approximately 12%, and several modifications to the mechanical design improved the pointing performance of the observatory by attenuating the day/night transition disturbances in the Solar Arrays. To improve memory and computational speed, a coprocessor was also added to the existing computer.

Servicing Mission 2
The Second Servicing Mission (SM2) in February 1997 significantly improved HST's productivity. This servicing mission was again a combination of new instruments, vehicle enhancements, and replacing failed or degraded components. The two new technology instruments were the Space Telescope Imaging Spectrograph (STIS) and Near Infrared Camera and Multi-Object Spectrometer (NICMOS). On the observatory side, Fine Guidance Sensor-1 (FGS-1), one of three FGS's, was replaced due to bearing wear. Upgrades to the replacement FGS increased its ability to minimize spherical aberration, regaining its sensitivity to guide stars from 14 to 14.5 magnitude. The other two Fine Guidance Sensors were planned for changeout on future servicing missions. Two of three mechanical tape recorders were replaced; a failed unit was replaced by an identical one, and the second by a higher capacity digital

Solid State Recorder, vastly increasing HST's data storage capacity from 4 to 14 Gbits. One of HST's four Reaction Wheel Assemblies was replaced to ensure redundancy in the HST's pointing control system. The damaged Data Interface Unit-2 was replaced with a modified and upgraded unit to correct for known failure modes. The second of two Solar Array Drive Electronics was replaced to correct potential failure modes.

Servicing Mission 3A

SM3, was originally a scheduled mission of upgrades and preventive maintenance. However, a new urgency prevailed on November 13, 1999, when the fourth of six gyroscopes failed and HST entered a non-productive safe-mode to protect the vehicle. NASA had already decided to split SM3 into two parts, SM3A and SM3B, after the third of HST's six gyroscopes failed. A rapid response mission was developed, and executed in a record 9 months.

SM3A in December 1999 recovered HST's ability to do science data gathering. The equipment installed included three new Rate Sensor Units (six gyros), a Battery Voltage/ Temperature Improvement Kit to optimize battery charging and maximize battery state of charge, a second Solid State Recorder to replace one of the two remaining mechanical recorders-increasing storage capacity to 24 Gbits, an S-Band Single Access Transmitter to replace a failed unit, an upgraded Fine Guidance Sensor to replace the second of three with one optimized for operation with spherical aberration, and a new 486-based computer to replace the existing spacecraft computer with a more capable unit that increased computing capacity by a factor of 20. Some of the degraded external thermal blankets were also repaired.

Servicing Mission 3B

The second half of the split mission, SM3B, launched in March 2002, and installed the other components originally planned for the SM3 mission, again dramatically improving the observatory capabilities. One of these was a major update to the vehicle's power system, where the Power Control Unit and Solar Arrays were both replaced, increasing available power approximately 37%. The PCU changeout was significant in that HST had to be completely powered off in-orbit, something that had never been done since launch. Successfully replacing the PCU allowed full use of all the Solar Array power. Additionally, the new Solar Array-3 dramatically improves power output for the remaining life of HST. Perhaps the most significant benefit from the new Solar Arrays is a decrease in the overall vehicle jitter by a factor of 25 by replacing the flexible arrays with a rigid design. A Reaction Wheel Assembly and new thermal control blankets were also installed on this mission to improve observatory robustness by correcting degraded hardware.

The second dramatic change for SM3B was the installation of the NICMOS Cooling System to compensate for depletion of the instrument's original solid nitrogen cryogen. The new cooling system allowed the NICMOS detectors to be re-cooled to approximately 77K and revived HST's infrared capabilities. The cooling system uses a super-quiet cryocooler with ultra-high speed micro-turbines, the fastest of which spins at over 400,000 rpm. The ability to change the detector set-point temperature increased the quantum efficiency of NICMOS by ~ 30 to 50% (wavelength dependent). The heat generated by the mechanical cryocooler is conducted to the external environment via a Capillary Pumped Loop heat pipe connected to a new external radiator. A major, technologically advanced new instrument, the Advanced Camera for Surveys (ACS) was installed in SM3B. Additional repairs were made to the external thermal blanketing.

Servicing Mission 4

The next servicing mission, SM4, has a tentative launch date of mid 2005. Astronauts will install two, new science instruments: the Cosmic Origins Spectrograph and a new Wide Field Camera 3. This mission will be used to replace all the RSUs (currently two of six gyros have failed), replace the batteries to ensure life thru at least 2010, replace the third and final FGS, and install additional thermal control blankets. Another external radiator will be installed that will connect to the other three Science Instruments to provide cooling to their detectors and help increase detector efficiency. A cross-strapping box will be installed in the science data path to increase the reliability of these systems and ensure our ability to access the scientific data.

Improvement Trend In Performance Parameters

	Launch	**SM1**	**SM2**	**SM3A**	**SM3B**	**SM4**
Data Storage (G Bits)	3	–	12	21	–	–
Computer Processing Power (MIPS)	0.35	4.55	–	91.00	–	–
Total Avail. Power (W)	2495	2495[1]	2270	2150	[2]2835	2770 (est.)
Power Avail. To SIs (W)	1080	1190	1035	1000	1760	1640 (est.)
Power Required by SIs (W)	500	465	690	655	1260	1505 (est.)
Aft Shroud Heat Transport - Radiated	531	466	566	–	695	645
Aft Shroud Heat Transport - Conducted	0	–	–	–	345	510
Peak Science Jitter (mas, 60-second rms) all disturbances	39	23	–	–	14	–
Peak Science Jitter (mas, 60-second rms) disturbances occurring at least once per orbit	36	21	–	–	6	–
Quiescent Science Jitter (mas, 60-second rms)	3 30% of orbit time	3 35% of orbit time	–	–	3 95% of orbit time	–
Cryogenic Cooling	None	None	Frozen nitrogen 70K	None	Mechanical cryocooler 74K	None

[1] Prior to Solar Array replacement on SM1, available power was 2255W

[2] Prior to Solar Array replacement on SM3B, available power was 2090W